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YARN MAKING PROCESS AND APPARATUS

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to the synergistic combination of an air shield and a tension gate apparatus and a process for operating the synergistic combination in a relax zone during yarn production. Both the air shield and the tension gate apparatus are incorporated into a relax zone in the production of yarn to increase the stability of the yarn on the relax rolls, especially at process speeds greater than 4,000 meters per minute. In particular, the present invention relates to that portion of yarn production wherein the yarn is relaxed to control its shrinkage without decreasing the yarn stability on the relax rolls. Typical processes that have apparatus for relaxing the yarn during production are spin-drawing, draw-twisting, draw-winding, and draw-bulking processes.

(2) Prior Art

It is known to use air shields in a relax stage of yarn production. It is also known to employ a tension gate in a relax zone.

U.S. Patent 5,240,667 to Andrews, Jr., et al., discloses a nylon yarn production process having a relax zone between pairs of rollers. Specifically, one pair of rolls operate at a process speed approximately 11% lower than the speed of another pair of rolls. Between the roll pairs are a pair of snubbing pins which act to increase the tension on the yarn advancing onto the pair of rolls following the pins. This patent discusses wind-up speeds of over 2,000 yards per minute and preferably 2,400 yards per minute. Whereas the present invention is looking at speeds over 3,500 meters per minute and preferably over 5,000 meters per minute. The snubbing pins employed at the speeds mentioned in the Andrews, Jr., et al. patent are suitable for nylon, however at the

increased speeds of the present invention, snubbing pins are not suitable for polyester in that they abrade and fray the polyester such that it is of poor mechanical quality. This patent does not teach the use of air shields.

The following patents relate to employing an air shield during yarn production. Generally these patents teach employing an air shield, with or without holes, near a pair of godet roll. None of these patents teach employing the air shield with a tension gate.

Japanese Patent 58-26767 to Ishihara Masatoshi, et al. assigned to Toray Industries, Inc., describes air shield plates used to prevent yarn vibration thereby enhancing the quality of the wound yarn in high speed winding applications. This patent employs restricting guides as well as the air shield plates in Figure 2 of JP 58-26767.

Japanese Patent 62-116477 to Ohata Takahiro, et al. assigned to Teijin Seiki Company, Ltd., discloses an air shield plate positioned between a pair of godet rolls to prevent the occurrence of vibration of the yarn.

Korean Patent Applications 94-4689 and 94-4690 by Baek, et al. and assigned to Cheil Synthetics, Inc., both relate to employing multi-hole air shield plates near the first godet roll to be used at high speeds above 6,000 meters per minute to prevent air flow thereby reducing fiber breakage and ensure high productivity of the process.

Japanese Patent 2761789 to Takashi Inoue, and assigned to Teijin Seiki, Co., Ltd., describes an air shield type device. Specifically, two godet rolls are employed where yarn moves excessively on the roll surfaces. Each godet pair consists of a driven roll and a separator roll. The air shield is a single plate mounted between the rolls with one edge in close proximity to the driven godet roll surface. The plate is perforated with multiple holes which break up the deflected air stream that bounces off the plate and reduces the incidence of roll wrap.

Despite all of the prior art listed above, there is still a need in the marketplace to improve the yarn stability and the frays and breaks that occur during textile fiber manufacturing. This need increases as the windup speed increases. There is also a need in the art to provide greater relax on the rolls without losing the stability of the yarn as it traverses the rolls. Both of these needs are satisfied by the present invention.

SUMMARY OF THE INVENTION

The present invention relates to the combination of a tension gate and an air shield. Not only is the combination not known in the prior art, but the combination gives a synergistic effect over using either an air shield alone or a tension gate alone. The air shield can be any blocking type plates with or without perforations. Furthermore, these air shields may be placed in close proximity to the pair of relax rolls following the tension gate present in the relax zone of a fiber producing process. The plates are positioned on the inside of the threadline so that the airflow is substantially reduced around the threadline. The tension gate can be one or more air drag devices, one or more liquid drag devices, one or more solid surface contact devices, or a combination of any of these, as disclosed by the inventor in U.S.S.N. 09/613,225 filed on July 10, 2000. The preferred embodiment of the present invention is with a tension gate comprising one or more rolls in the relax area of the fiber production process with air shields positioned on the inside of the fiber string up (threadline) between the pair of rolls following the tension gate.

In the broadest sense, the present invention comprises, for use in a relaxation zone of a fiber production process, an air shield and a tension gate.

Likewise, the present invention relates to a process for producing fibers in a relax zone comprising the steps of introducing a tension gate in the relaxation zone; and introducing an air shield around the pair of rolls (relax rolls) following said tension gate in the fiber relaxation zone.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings are to aid one skilled in the art in understanding the present invention and its related concepts as well as the scope of the invention. However, the drawings are in no way meant to limit the scope of the invention or impose any limitation on the invention beyond that set forth in the claims.

Figure 1 shows a schematic of the combination of an air shield and a tension gate apparatus with the air shield positioned inside the threadline between the two rolls following the tension gate.

Figure 2 shows a second schematic of the combination of an air shield and a tension gate apparatus where the tension gate has an additional threadline drag device.

Figure 3 is a side schematic view of the rolls following the tension gate, with the air shield positioned inside the threadline between the two rolls.

Figure 4 is a graph of process speed versus yarn stability on the relax rolls.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Applicant has filed a patent application on tension gates and their use in a relaxation zone in a fiber production process. U.S.S.N. 09/613,225 to DeBenedictis, et al. filed July 10, 2000 is hereby incorporated by reference.

The present invention is the combination of air shields and tension gate devices. Current processes such as a spin draw process, draw twisting process, draw-winding process, or draw bulking process include a relax zone and thus the process and apparatus of the present invention can be employed in such a relax zone. Any melt-spun polymer employed with any of the above processes such as polyesters, polyamides (nylons), polyolefins, polyketones, polyetherketones, polyphenylene sulfide, and polyarylates can be employed with the present invention. Typical polyesters are polyethylene

terephthalate, polybutylene terephthalate, polypropylene terephthalate, polyethylene naphthalate, or a mixture of any of these, or copolymers of any of these polyesters with up to about 15% by weight of polyolefins, poly-alkylene glycol, or other copolyesters such as polyethylene terephthalate isophthalate. Typical nylons are nylon 6 and nylon 66. Typical polyolefins are polyethylene, polypropylene, polybutylene, or a mixture of these. Combinations of any of these polymers, or any one of these polymers with other polymers like polyethylene or polypropylene, in the form of a bicomponent or heterofil fiber are also within the scope of the present invention.

As the relax level increases, yarn tension in the relax zone decreases, and this causes the yarn to become unstable on the rolls downstream of the relax zone. As process speeds increase, stability becomes worse, at a constant relax ratio, due to the increase in centrifugal force on the yarns on the relax rolls. Thus as process speeds are increased, relax level must be decreased to maintain stability. Unstable yarn is defined as yarn moving, or swaying across the roll surface due to low tension. Highly unstable yarn can lead to a reduction in mechanical quality, and in severe cases, to breakouts (yarn breakage).

When the process or apparatus of the present invention is used in any of the yarn production processes having a relax zone, a higher level of relax and a resulting lower hot air shrinkage can be achieved as compared to conventional processes and apparatuses. By using the present invention at higher processing speeds one can achieve the same level of relax under high speed conditions versus more conventional low speed conditions, or one could maintain the process speed but increase the level of relax such that the hot air shrinkage is greatly improved (reduced), or both can be done simultaneously.

The tension gate of the present invention partitions a relax zone in a conventional process into a relax zone and a small stretching zone. Different devices, when positioned in a conventional relax zone can create a partition. Tension gates can be created by applying drag to the yarn, by means of air drag, liquid drag, or drag produced by pulling the yarn over a solid surface. Air drag can be applied to the yarn by employing one or

more interminglers or a counter-current air-flow device, for example. The air pressure for the air drag device is typically from 5 to 50 psi, and more typically 10 to 40 psi and preferably between about 10 to 30 psi. The air pressure blowing across the threadline can be directly related to the amount of tension the intermingler places on the threadline. The higher the air pressure, the higher the tension.

Liquid drag can be introduced by employing one or more finish applicators (a finish applicators is a device well known to those in the textile industry, as it applies a liquid finish or coating to the yarn), or by drawing the yarn through a pool of liquid, for example. Applying liquid at a rate of about 4 – 7 ml. per min. for 1000 denier yarn is typical. The application rate varies with the process speed, denier, and desired tension, as well as other factors known to those skilled in the art.

Solid surface drag can be introduced by contacting the yarn with one or more solid surfaces (like rolls) over or around which the yarn traverses, but because the yarn does not have multiple wraps on a roll, traversing and swaying yarn on the tension gate device is not a problem, and does not cause yarn breakage. In situations where it is desirable to achieve only a low tension gradient (e.g. 5 mg/d) across a free-wheeling roll or rolls, or situations where it is desirable to limit the tension gradient across such rolls, it may be necessary to assist the rotation of one or more tension gate rolls. In other words, a free-wheeling roll has sufficient bearing friction and air drag that it may be difficult to achieve a tension gradient of only about 5 mg/d, because the total rolling resistance may exceed the tension gradient. To achieve a low tension gradient, it may be desirable to assist the rolls in their rotation by employing a turbine drive wherein air is employed to help drive the rolls. Operating the rolls with turbine drives or with very sensitive secondary assistance such as electric motors is well within the scope of the skilled artisan and within the present invention.

A tension gate is a device which when used in a relax zone of a yarn production process has an outlet yarn tension greater than the inlet yarn tension thus creating a tension differential. Additionally, tension gates of the present invention comprising one or more rolls are non-multiwrap yarn roll devices. The tension differential is generally

greater than 5 milligrams per denier (mg/d) such that if the yarn is a 1,000 denier yarn, then the tension gate of the present invention is 5 grams, whereas if the yarn has a 2,000 denier, then the tension gate is at least about 10 grams. For the present invention a preferred embodiment is a tension gate or a process having a tension differential of at least about 7 mg per denier, and more preferable greater than about 9 mg per denier. Use of the tension gate and process of the present invention in the relax zone of a yarn production system allows higher levels of relax and corresponding significant reductions in hot air shrinkage of the yarn at the same processing speeds.

If we assume that a significant improvement in process speed is 10%, or if we assume that a significant increase in the relax level is 15%, then a tension gate which has about 7 mg per denier of tension differential between the yarn leaving the tension gate versus the yarn entering the tension gate achieves the significant improvement. This is the preferred embodiment. Of course, good stability can result even when the process speed is improved less than 10% and/or the relax level is increased less than 15%. Such results are not characterized as a "significant improvement", but are within the scope of the present invention.

Figure 1 schematically illustrates the present invention comprising the combination of a tension gate and air shields. Referring to Figure 1, reference 10 generally indicates the apparatus of the present invention positioned in a relax zone of a fiber production process. The relax zone has a pair of draw rolls 12,14 spaced apart and a fiber threadline 16 is multiply wrapped around the draw rolls 12,14. After the draw rolls, the threadline 16 proceeds to the tension gate device 18 and from the tension gate device to a pair of relax rolls 20,22 (thus rolls 20,22 follow the tension gate in the threadline path). The pair of relax rolls have an air shield generally indicated by reference numeral 24 mounted adjacent the rolls 20,22 and are spaced approximately 1 cm from the rolls. The shield 24 may be perforated or solid as known in the art. The air shield 24 is supported by a support frame (not shown) that may be secured to the supporting framework (also not shown) for the rolls 20,22. The air shield is positioned inside of the threadline 16 so that airflow is blocked from blowing across the threadline and creating movement on the rolls 20,22. The air shield 24 comprises at least one plate

(thin and flat – substantially two dimensional) and preferably a pair of plates 26,28. The plates may be made from any material capable of being perforated or being solid such as metal, like aluminum or copper for example (virtually any metal will perform equally well); plastic like polycarbonate, polyester, polyamide, all of which are well known in the art; wood, rubber; or a combination of these. Preferably the spaced apart plates 26,28 are positioned between the relax rolls 20,22 and within each tangent line connecting the outer surface of each roll, and thus within the threadline 16. The plates blocks the flow of air generated by the rotation of the rolls 20,22 and any airflow caused by fans or blowers in a production facility, for example. By virtue of the fact that the air shield 24 is positioned approximately 1 cm from rolls 20,22 and are also about the same distance from the threadline 16, a quiescent zone adjacent the air shield 24 is created thus significantly reducing any disruption of the movement of the threadline on rolls 20,22 induced by air currents.

The tension gate device 18 can be of any device discussed in the prior patent application of the inventor such as one or more air drag devices, one or more liquid drag devices, one or more solid surface contact devices, or a combination of two or more of any of these. With respect to Figure 1, the tension gate device comprises a pair of rolls 30,32. The yarn exiting the tension gate 18 has a greater tension than the yarn entering the tension gate.

In operation of the Figure 1 device, a threadline 16 coming from the draw stage (not shown), for example, is multiple wrapped about the pair of rolls 12,14. The function of the rolls 12,14 is not a part of the present invention and depends upon the type of process in which the relax zone is present (the relax zone includes the rolls 12,14 the tension gate 18 and the rolls 20,22). The roll pair 12,14 have a process speed (velocity) that is faster than the roll pair 20,22, and thus during operation the yarn relaxes. Therefore the rolls 12,14 could be a pair of draw rolls in a spin-drawing process, or a pair of rolls in a draw-twisting process, or a pair of rolls in a draw-winding process, or a pair of rolls in a draw bulking process. Upon exiting the pair of rolls 12,14 the threadline 16 enters the tension gate 18. The tension gate in Figure 1 comprises a pair of rolls 30,32 which increase the tension on the threadline compared to the tension

of the threadline entering the tension gate. The threadline 16 then proceeds to a pair of rolls 20,22 that may be a pair of relax rolls, for example. The threadline is multiply wrapped about the rolls 20,22 and exits the rolls to further processing or winding. Adjacent the rolls 20,22 are the plates 26,28 and the threadline 16 passes in close proximity to the outside surface of the plates. Because the plates 26,28 are positioned inside of the threadline created by the multiple wraps of the yarn or fiber 16, as shown in Figure 3, the air shield 24 does not interfere with string-up, for example. The tension gate 18 increases the tension from the inlet of the tension gate to the outlet of the tension gate on the threadline 16 by virtue of the speed of rotation of the rolls 30,32. The first roll 30 in the tension gate may typically rotate at a speed less than the rolls 12,14. The second roll 32 of the tension gate has a rotational speed higher than the first roll 30 and preferably at the same speed or slightly less than the speed of the rolls 20,22 thereby maintaining a tight wrap about rolls 20,22 thereby increasing the stability on these rolls.

Figure 2 illustrates a second modification of the present invention in which an air drag device or a liquid drag device 34 is employed in combination with the pair of rolls 30,32 in the tension gate. This combination of devices to produce a tension gate device 18 is disclosed in the patent application of the inventor previously referenced. The operation of the Figure 2 device is substantially similar to that of the Figure 1 device with the obvious exception that the threadline 16 upon leaving the rolls 12,14 passes first through the air or liquid drag device 34 then onto the pair of rolls 30,32. The air or liquid drag device 34 provides tension to the threadline 16 coming from that portion of the relax zone located between the rolls 12,14 and the tension gate 18, for example.

With reference to Figure 3, a side view of rolls 20,22 is illustrated. Positioned between the rolls 20,22 is the plate 28 which is inside the threadline, thus permitting the viewer to see the wraps of the threadline about the rolls 20,22 and extending outside of the plate 28 (the plate 28 is positioned inside of a tangent line of the rolls 20,22). With the wraps positioned outside of the plate 28, the plate does not interfere with string-up of the apparatus. When viewing Figure 3, the threadline 16 comes from the tension gate on the top of the right side of roll 20, wraps around the rolls 20,22, and exits from the top of the left-hand side of roll 20, for further processing or wind-up.

The roll pairs 12,14 and 20,22 can be the same or different sizes. Additionally, the pair of rolls 12,14 or the pair of rolls 20,22 are not necessary the same size either. For example roll 12 can be a driven roll and roll 14 a smaller separator roll, similarly roll 20 can be a driven roll and roll 22 a smaller separator roll.

Examples

Polyester polymer was extruded through a spinneret, spun, drawn and relaxed in a conventional spin-draw process. The spun yarn IV was 0.88 (measured in orthochlorophenol at 25^0 C.).

The spun yarn was drawn in a two-stage process. The final draw rolls had a temperature of 242^0 C. The yarn was relaxed 9.62% between these draw rolls and a pair of relax rolls at 240^0 C.

The initial conditions were a spinning speed of 678 mpm and a final draw speed of 3658 mpm. The final draw speed was increased in 250 mpm increments to create the lines in Figure 4, with an increase in the spinning speed to maintain constant yarn physical properties (tenacity and elongation). The throughput was adjusted (increased) to maintain a final drawn denier of 1000. The yarn stability of the wraps on the relax rolls was recorded as a function of the draw roll speed.

A subjective scale is used to define the yarn stability. A rating of 1 (excellent) is defined as extremely stable with no threadline movement or swaying, while a rating of 5 (extremely poor) is defined as sufficient yarn movement that the threadline immediately breaks. A rating of 3.0 to 3.5 is considered the maximum level of instability permitted in a manufacturing process. Acceptable preferred stability is from 1.0 to 2.5.

Example 1

Run 1 had no tension gate or air stripper between the relax rolls (control).

Run 2 had a tension gate consisting of 2 air driven rollers as schematically shown in Figure 1. The break angle over the first roll was 161 degrees, and the break angle of the second roll was 175 degrees. This created a tension gate of 55-70 grams.

Run 3 utilized air stripper plates between the pair of relax rolls, positioned about 1 cm. from the rolls.

Run 4 combined both the tension gate of run 2 and the air stripper plates of run 3.

Figure 4 shows the yarn stability on the first set of rolls following the tension gate as a function of draw speed for these runs. In particular, the draw speed is measured on the draw rolls just prior to the tension gate, measured in meters per minute (mpm). From this Figure the process speed corresponding to a yarn stability rating of 3 is shown in Table 1.

Table 1

Run	Speed, mpm	Increase over run 1
1	4,180	
2	4,540	360
3	4,460	260
4	5,280	1,100

It was believed that the combination would not yield a result significantly better than the air shield alone or the tension gate alone because once the yarns on the relax rolls were stable, only a minor improvement at best could be expected. The best that could be expected was that the combination of the tension gate and air stripper would be additive, i.e. a speed increase of 620 mpm, while maintaining a stability rating of 3. Surprisingly it was 60% higher at 1,100 mpm, thus illustrating a synergistic effect.

Example 2

Using the configuration of Example 1, Run 4, an additional tension gate was added prior to the two roll tension gate as illustrated in Figure 2. This tension gate was an air intermingler operating at a pressure of 30 psig. A draw speed of 5000 mpm was used, with a relax ratio of 8.91% onto the relax rolls at a temperature of 150° C (the draw rolls were maintained at 242° C).

At 5,000 mpm, the threadline stability improved from 3.0 to 2.75 when the air was supplied to the intermingler.

Thus it is apparent that there has been provided in accordance with the invention a process and an apparatus that fully satisfies the objects, aims, and advantages set forth above. While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and the broad scope of the claims.